On the distinction between sensory storage and short-term visual memory*

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A pattern made by randomly filling cells in a square matrix was presented for 1 sec and followed, after various intervals, by an identical or similar pattern. Ss responded "same" or "different." Performance was fast and accurate if the interval was short and there was no movement or masking of the pattern during the interval. Performance was slower, less accurate, and highly dependent on pattern complexity if the interval exceeded 100 msec or if there was movement or masking. The results are interpreted as evidence for two distinct classes of visual memory: high-capacity sensory storage which is tied to spatial position and is maskable and brief; and schematic short-term visual memory which is not tied to spatial position, which is protected against masking, and which becomes less effective over the first few seconds but not over the first 600 msec.

There is evidence that visual input is represented in human memory in at least three distinct ways: as a detailed sensory representation, as a verbal description, and as a schematic representation of visual structure. The evidence for sensory storage is voluminous and well known (e.g., Sperling, 1963; Eriksen & Collins, 1968). It is also clear that we are able to produce and remember verbal descriptions that capture at least some aspects of visual input. Experimental evidence frequently quoted is that of Carmichael, Hogan, & Walter (1932), Conrad (1964), and Glanzer & Clark (1964). Evidence for a schematic visual representation is implicit in the fact that most uses of visual input must be based upon an articulation of the patterns of stimulation into objects and their relations. Examples of recent evidence for memory involving schematic visual representations are the findings of Posner (1969) and Kroll et al (1970). In a long series of experiments, Posner has studied the reaction time for the comparison of successively presented letters, and has shown that, under some conditions, comparisons that can be made upon the basis of visual appearance (e.g., A followed by A) are faster than comparisons that cannot (e.g., A followed by a). Kroll et al have shown that the recall of visually presented letters is less affected by verbal shadowing during the retention interval than is the recall of spoken letter. Both sets of findings have been taken as evidence that letters may be represented either by their names or by some kind of visual code related to their appearance.

If there is a distinct schematic visual memory, then it may be possible to obtain evidence for it by showing that there is a memory for visual input under conditions that are suited to neither sensory nor verbal memory. Evidence of this kind has been reported by Phillips and Baddeley (1971) and by Cermak (1971), who studied the comparison of two successively presented novel visual configurations that were either identical or very similar. Comparisons were fast and accurate when the interstimulus interval (ISI) was short, and became slower and less accurate as ISI was increased up to 9 sec in the former study and up to 20 sec in the latter study. These results were interpreted as evidence for a short-term visual memory (STVM). It was assumed that verbal memory played no significant role in these experiments because patterns were used that seemed adapted to our visual descriptive capacities but not to our verbal descriptive capacities. It was assumed that sensory storage played no significant role because storage time was too long and because, in the Phillips and Baddeley study, a masking field was used. The aim of the present experiments was to investigate further the properties of STVM, and in particular those which distinguish it from sensory storage.

There seems to have been no direct comparisons between sensory storage and STVM, but most of the available evidence suggests that they are quite distinct. Not all of it does, however, and views on the issue vary widely. Coltheart (1972), in discussing the evidence on the visual code studied by Posner's reaction time technique, suggests that it differs from sensory storage with respect to capacity, maskability, dependence on display parameters, and dependence on central processing capacity. Posner's own accounts, however, involve only one form of visual memory—the visual code—and this is sometimes

described as a realtively pure visual or physical trace (Posner &Warren, 1972). Shaffer and Shiffrin (1972) report evidence which they suggest tends to blur the theoretical distinction between sensory storage and STVM. Their Ss saw a series of 120 pictures of natural objects and scenes, and then a test series in which 60 of these pictures were shown again randomly mixed with 60 new pictures. Increasing the display time of pictures in the original series increased recognition confidence ratings, but increasing the blank time between pictures in the original series had no effect. These results were interpreted as evidence that such complex visual stimuli are available for processing only during the period for which they are physically exposed. Shaffer and Shiffrin note, however, that if the relevant stimulus is less complex, such as when Ss must remember the position of a dot on a line, then there is evidence for a visual memory lasting several seconds (Posner & Konick, 1966). They therefore suggest that there may be just one kind of visual memory in which decay rate is dependent on complexity. Finally, Pollack (1972), studying a situation thought to be similar to that of Phillips and Baddeley (1971), found no evidence for visual memory other than could be accounted for by some kind of sensory storage. His results therefore question the existence of an STVM distinct from sensory storage.

The methods used in the present experiments were essentially those of Phillips and Baddeley (1971). In three experiments, the effects of pattern complexity, pattern movement, and masking were studied over a range of ISIs.

GENERAL METHODS

The experiments were conducted on-line to an Elliot 4130 computer, and the patterns were presented on an Elliot 4280 graphical display unit. Block patterns were formed by lighting randomly selected cells in a square matrix. The probability of any cell being lit was 0.5, and new patterns were formed on each trial. The number of cells in the matrix will be called the matrix size, and this varied from 4 by 4 cells to 8 by 8 cells. The size of each cell was 0.12 x 0.12 in., and viewing distance was about 15 in. Each cell therefore subtended a visual angle of about 27 min.

At the beginning of each trial, a fixation point appeared on the screen, and when ready, S triggered the onset of the display sequence. Pattern 1 was displayed for 1 sec, and followed after a randomly selected delay by Pattern 2, which was displayed until S made his response. Pattern 2 was either identical to Pattern 1 or differed by having one cell more or one cell less filled. Ss were instructed to decide "as quickly as possible without error" whether the two patterns were the same or different and to press one of two display console keys accordingly. Same and different trials occurred at random and with equal probability. On different trials, the cell to be changed was randomly selected. All conditions within an experiment varied randomly across trials. The S's response, his reaction time as measured from the onset of Pattern 2, and the position and nature of any change in the pattern were automatically recorded. The Ss were students and staff of the University of Sussex, and they were tested individually in sessions lasting about 50 min.

To obtain a rough indication of the ease with which such patterns can be described verbally, four Ss were asked to write, as quickly as possible, brief but accurate descriptions of 10 different 5 by 5 block patterns. In a recall test about 1 h later they were asked to reproduce the patterns by filling cells in empty 5 by 5 matrices, and were given their own written descriptions to help them in this task. The mean number of words written per pattern was 116, and the mean time taken to write these descriptions was 244 sec per pattern. The percentage of cells correctly filled at recall was 91.6%.

EXPERIMENT I: COMPLEXITY AND ISI

Short-term forgetting over blank ISIs of 0.02, 1.0, 3.0, and 9.0 sec was studied with block patterns in 4 by 4, 6 by 6, and 8 by 8 matrices. Six Ss each performed 30 trials in each of the 12 possible conditions. Trials occurred in random order within each of 5 blocks, with 6 trials per condition per block.

Results

The percentages of correct response, over all Ss, are shown in Fig. 1 as a function of ISI and matrix size. Chance performance in this and in the following experiments is 50%. An analysis of variance performed on the number of responses correct, with Ss as replications, shows highly significant effects of both ISI, $F(3/60) = 67.65$, $p < .0001$, and matrix size, $F(2/60) = 56.01$, $p < .0001$. The interaction of ISI and matrix size was also highly significant, $F(6/60) = 5.37$, $p = .0004$. The effect of matrix size therefore depends upon the ISI, and when ISI was .02 sec the proportion of correct responses was not significantly less for 8 by 8 matrices than for 4 by 4 matrices, $Z = 1.41$, $p = 0.16$.

The effects of complexity and ISI seem much too large to be due simply to changes in criterion, and this is supported by calculation values for d' and β shown in Table 1.
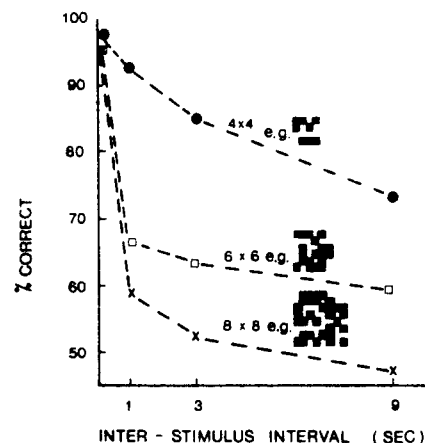

Fig. 1. Experiment I. Percentage of correct responses as function of ISI and matrix size.

Table 1
The Total Number of Hits and False Alarms (Max = 90) and the Values of d′ and β Calculated from Them for Experiment I

Matrix Size	ISI	Hits	False Alarms	d′	β
4 by 4	.02	87	0		
	1.00	83	6	2.9	1.15
	3.00	85	22	2.26	.39
	9.00	78	36	1.38	.55
6 by 6	.02	81	0		
	1.00	47	17	.93	1.46
	3.00	59	36	.65	.95
	9.00	70	54	.52	.77
8 by 8	.02	81	0		
	1.00	32	18	.47	1.33
	3.00	47	43	.10	1.00
	9.00	62	68	−.16	1.14

Mean reaction times for correct different judgments, over all Ss, are shown in Fig. 2 as a function of matrix size and ISI. These two variables affect reaction time in very much the same way as they affect accuracy. At ISIs of 1 sec or more, reaction times were highly dependent on matrix size. When the ISI was .02 sec, however, an increase in matrix size from 4 by 4 to 8 by 8 had little effect on reaction time. The reaction times for correct same judgments show similar effects, except that they were longer when ISI was .02 sec than when it was 1 sec. This is probably because when ISI is very short, the offset of Pattern 1 and onset of Pattern 2 is difficult to detect if the pattern does not change (Phillips & Singer, 1974).

At first sight, the results support the suggestion of Shaffer and Shiffrin (1972) that there is a single visual memory in which decay rate is dependent on complexity. Indeed, the results bear a close resemblance to the findings in verbal memory experiments that Melton (1963) has used to argue for a single verbal memory. One reason for doubting this interpretatio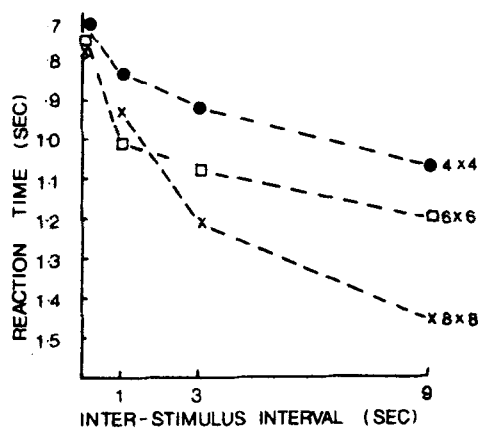n is that in the present experiments the phenomenal experience is quite different at long and short ISIs. At long ISIs, the experience is that of knowing that the two patterns are of different shape, whereas at short ISIs, the experience is that of actually seeing the change happen. In the latter case, the experience is that of seeing appearance, disappearance, or apparent movement depending upon the kind of change made and the way in which the cells around it are filled. Evidence that two distinct forms of visual memory are involved is provided by the following experiments, which show that seeing the change happen and knowing that the shapes differ depend upon quite different variables.

EXPERIMENT II: POSITION, COMPLEXITY, AND ISI

Method

As in the previous experiment, Pattern 1 was displayed for 1 sec, and was followed by a blank ISI of variable duration. In this experiment, however, Pattern 2 was not always displayed in exactly the same position as Pattern 1. On half of the trials, at random, Pattern 2 was displayed moved horizontally by the width of one cell either to the left or right at random. Performance was studied over ISIs of 0.02, 0.06, 0.1, 0.3, and 0.6 sec, and with block patterns in 5 by 5 and 8 by 8 matrices. Five Ss each performed 40 trials in each of the 20 possible conditions. Trials occurred in random order within each of 10 blocks, with 4 trials per condition per block.

Results

The percentages of correct response, over all Ss, are shown in Fig. 3 as a function of ISI, matrix size, and position. A three-way analysis of variance shows highly significant effects of all three variables: for ISI, $F(4/80) = 9.08$, $p < .0001$; for matrix size, $F(1/80) = 197.17$, $p < .0001$; and for position, $F(1/80) = 45.43$, $p < .0001$. The interaction of position with duration is also highly significant, $F(4/80) = 14.24$, $p < .0001$. Position had a large effect on accuracy when ISI was short but had little effect on accuracy when ISI was more than 100 msec.

Fig. 2. Experiment I. Mean reaction times for correct "different" responses as a function of ISI and matrix size.
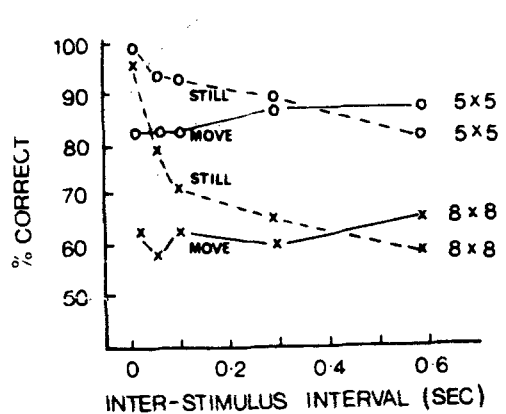

Fig. 3. Experiment II. Percentage of correct responses as a function of ISI, matrix size, and movement.

Hit rates, false alarm rates, and values of d′ and β are given in Table 2.

When the pattern is still, performance was similar to that in the previous experiment. A two-way analysis of variance performed on the still conditions alone shows highly significant effects of complexity, $F(1/40) = 72.33$, $p < .0001$, of ISI, $F(4/40) = 22.45$, $p < .0001$, and of their interaction, $F(4/40) = 3.34$, $p = .019$.

When the pattern was moved, performance was determined only by matrix size. A two-way analysis of variance performed on the move conditions alone shows highly significant effects of matrix size, $F(1/40) = 129.15$, $p < .0001$, but no effect of ISI, $F(4/40) = 0.70$, $p = .60$, or of its interaction with matrix size, $F(4/40) = 0.49$, $p = .74$. The phenomenal experience under these conditions is that of seeing the pattern move, and of knowing, on some occasions, that its shape had changed. The apparent motion was of the pattern as a whole, not of the changed element. Good apparent motion was obtained up to ISIs of at least 300 msec.

The reaction times for correct different judgments, averaged over Ss, are shown in Fig. 4. These results are again very similar to those for accuracy, and again show that when ISI is short reaction time is affected little or not at all by large increases in matrix size.

These results suggest that performance is made up of two components. The first component is observed at ISIs of about 100 msec or less and is of high accuracy. Moving the pattern, however, removes this component and performance therefore falls to the level set by the second component, which is not affected by pattern movement but which is affected by pattern complexity. The first component decays rapidly, and is associated with "seeing the change happen." The second component does not decay at all within the first 600 msec, and is associated with "knowing that the shapes differ." The final experiment seeks to determine whether these two components of performance differ in their sensitivity to masking.

# EXPERIMENT III: MASKING, COMPLEXITY, AND ISI

Method

This experiment was the same as Experiment II except that instead of displaying Pattern 2 in a new position a masking pattern was displayed in the interval between the two patterns. The mask was a checkerboard pattern in a 10 by 10 matrix with the same cell size as the test patterns and centered on the same point. It was displayed on half the trials at random. There were blank intervals of about 15 msec between Pattern 1 and the mask, and between the mask and Pattern 2. Performance was studied at ISIs of 0.04, 0.08, 0.12, 0.3, and 0.6 sec. and with block patterns in 5 by 5 and 8 by 8 matrices. Five Ss each performed 40 trials in each of the 20 possible conditions. Trials occurred in random order within each of 10 blocks, with 4 trials per condition per block.

Table 2
The Total Number of Hits and False Alarms (Max = 100) and the Values of d′ and β Calculated from Them for Experiment II

Matrix Size		ISI	Hits	False Alarms	d′	β
5 by 5	Still	.02	98	0		
		.06	89	1	3.55	7.06
		.10	89	4	2.98	2.18
		.30	82	6	2.47	2.20
		.60	67	7	1.92	2.70
	Move	.02	86	21	1.89	.77
		.06	90	24	1.99	.57
		.10	83	18	1.87	.96
		.30	82	10	2.20	1.50
		.60	83	12	2.13	1.27
8 by 8	Still	.02	94	3	3.44	1.75
		.06	59	2	2.28	8.03
		.10	50	7	1.48	2.97
		.30	39	10	1.00	2.21
		.60	31	16	.50	1.45
	Move	.02	67	43	.57	.92
		.06	59	45	.35	.98
		.10	55	31	.63	1.12
		.30	43	24	.53	1.26
		.60	43	13	.95	1.86

Results

The results are very similar to those of the previous experiment. The percentages of correct response are shown in Fig. 5, and the reaction times for correct different judgments are shown in Fig. 6. An analysis of variance on the number of correct responses shows highly significant effects of all main variables: for ISI, $F(4/80) = 6.0$, $p = .0005$; for matrix size, $F(1/80) = 169.62$, $p < .0001$; and for masking, $F(1/80) = 76.7$, $p < .0001$. The significant interaction terms show that matrix size has less effect at shorter ISIs, $F(4/80) = 3.22$, $p = .017$, and that masking has more effect at shorter ISIs, $F(4/80) = 5.07$, $p < .0014$. The
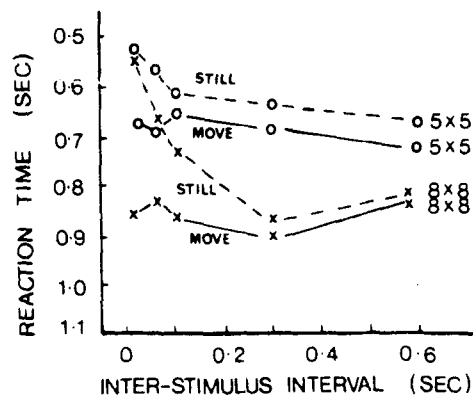
Fig. 4. Experiment II. Mean reaction times for correct "different" responses as a function of ISI, matrix size, and movement.
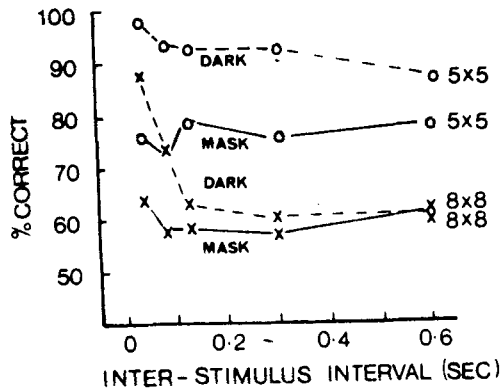
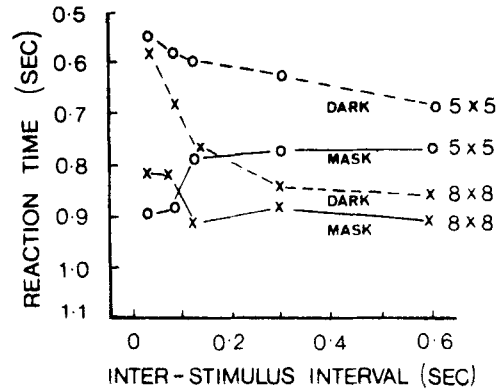Fig. 5. Experiment III. Percentage of correct responses as a function of ISI, matrix size, and masking.

Fig. 6. Experiment III. Mean reaction times for correct "different" responses as a function of ISI, matrix size, and masking.

shortest ISI used in this experiment was 40 msec, and not 20 msec as in the two previous experiments. As a result, performance with the 8 by 8 matrices in the dark condition did not quite reach the high level of accuracy previously obtained. Hit rates, false alarm rates, and estimates of d' and β are given in Table 3.

An analysis of variance performed on the mask conditions along shows highly significant effects of matrix size, F(1/40) = 40.16, p < .0001, but no effect of ISI, f(4/40) = 0.62, p = .65, or of its interaction with matrix size, F(4/40) = 0.39, p = .82. It is of interest to note that masking was fully effective when ISI was only 40 msec. In this condition, the mask was present for less than 20 msec, and was barely detectable.

These results therefore sem to show that the highly accurate position-sensitive component of performance is much more sensitive to masking. This effect, however, is not as clear for 5 by 5 matrices as it is for 8 by 8 matrices. The results agree with the previous experiment in showing that this performance deteriorates most rapidly over the first 100 msec, and in showing that the kind of performance limited by complexity does not deteriorate at all over the first 600 msec.

DISCUSSION

The results support the view that sensory storage and STVM are distinct, and suggest that some of their properties are as follows:

Sensory storage: (1) High capacity, as block patterns in 8 by 8 matrices at least can be handled with little loss. A limit must of course be met at some point, but what this limit is and what determines it is not yet known. (2) Tied to spatial position, as it can be used for pattern comparisons only if the two patterns appear in the same place. The frame with respect to which this position is specified cannot be determined from the above results because eye movements and the location of retinal stimulation were not controlled. (3) Highly sensitive to masking.

(4) Storage time of about 100 msec. (5) Concurrent and independent processing of elements across the visual field, as matrix size has little or no effect on reaction time.

Short-term visual memory: (1) Limited capacity, as not even a 4 by 4 block pattern can be handled without loss. (2) Not tied to spatial position, as it can be used to compare patterns appearing at different places. (3) Not necessarily masked by subsequent stimulation. As STVM is of limited capacity, this is presumably because input to it is determined by a control process, rather than because there is room for both pattern and mask. (4) No loss of efficiency over the first 600 msec, and then a slow loss over at least the first 9 sec, even if S has no other task to perform. The cause of this loss of efficiency is unclear, but it is very unlikely to be due to the sudden loss of the representation as a whole (Paivio & Bleasdale, 1973).

Table 3
The Total Number of Hits and False Alarms (Max = 100) and the Values of d' and β Calculated from Them for Experiment III

Matrix Size		ISI	Hits	False Alarms	d'	β
5 by 5	Dark	.04	98	1	4.38	1.82
		.08	97	8	3.29	.46
		.12	95	8	3.05	.69
		.30	90	5	2.93	1.70
		.60	88	13	2.30	.95
	Mask	.04	56	5	1.80	3.82
		.08	52	9	1.39	2.45
		.12	68	10	1.75	2.04
		.30	60	10	1.54	2.20
		.60	66	11	1.64	1.95
8 by 8	Dark	.04	81	5	2.52	2.63
		.08	60	11	1.48	2.06
		.12	45	19	.75	1.46
		.30	37	17	.62	1.49
		.60	45	25	.55	1.25
	Mask	.04	59	31	.72	1.10
		.08	57	41	.35	.98
		.12	54	36	.47	1.05
		.30	53	40	.33	1.03
		.60	46	25	.57	1.25

(5) Probably not concurrent and independent processing of elements, as reaction time increases with matrix size.

The move and mask conditions of Experiments II and III, respectively, both show that the performance associated with STVM can be obtained even when ISI is very short. Sensory and schematic representations therefore coexist.

The relationship between the sensory storage involved above and forms of sensory storage previously investigated is not simple. It is perhaps most similar to that studied in other experiments requiring S to detect a difference between two patterns (e.g., Lappin & Bell, 1972; Pollack, 1972). That some form of sensory storage is involved is indicated by the evidence for a high-capacity, rapidly decaying, maskable, topological representation. Further psychophysical and physiological investigations of this form of sensory storage suggest that its physiological basis is reciprocal inhibition between on-center and off-center cells in the lateral geniculate nucleus, and that its time course is determined by the decay of inhibition of on-center cells by off-center cells and by the time course of the transient component of the off response (Phillips & Singer, 1974; Singer & Phillips, 1974).

Can this form of sensory storage be identified with the icon? Iconic storage was originally described as the brief persistence of sensory impressions (Neisser, 1967), and as such seems to be the same as sensory storage. In this sense, iconic storage is involved above for the reasons already given. On the other hand, there are aspects of the above sensory storage which suggest that it may differ from some forms previously investigated. Three aspects will be mentioned. First, evidence for sensory storage was obtained with stimuli lasting for 1 sec. Further investigations indicate that increasing the initial stimulus duration does not remove the sensory storage involved above, and under some conditions may even lengthen it (Phillips & Singer, 1974). With other methods of investigation, however, sensory storage is observed only if the initial stimulus is brief, i.e., less than 250 msec (Haber, 1970; Eriksen, private communication), or less than 120 msec (Efron, 1970). Second, the storage time observed above was about 100 msec, even though both pre- and poststimulus fields were dark. Although this is similar to some previous estimates, it is shorter than many others (e.g., Haber & Standing, 1969). Third, the sensory component of performance in the present task seems to be removed by dichoptic presentation of the two patterns (Phillips & Singer, 1974). Haber and Standing (1969), however, found no effect of dichoptic stimulation. The sensory storage involved above therefore seems to differ in some ways from that previously described. Furthermore, comparison of previous results indicates that they differ among themselves with respect to at least storage time, effect of initial stimulus duration, and

stimulus luminance. These considerations suggest, therefore, in agreement with the recent suggestions of Turvey (1973) and Treisman, Russell, & Green (1974), that there may be a number of different types of sensory storage.

The sensory storage in the present experiments may involve that associated with the detection of apparent motion which requires some kind of storage during the interval between the two stimuli. This is suggested by the observation, noted earlier, that apparent motion is sometimes observed under these conditions. Three considerations argue against this possibility, however. First, apparent movement is not necessary for the effects reported (Phillips & Singer, 1974). Second, as already noted, the sensory component of the above performance is removed by dichoptic presentation, whereas the detection of apparent movement is not (Shipley, Kenney, & King, 1945). Third, the times involved seem different because apparent movement was observed with ISIs up to at least 300 msec, whereas the sensory component seemed to have mostly decayed by 100 msec.

The possibility of multiple sensory stores complicates the analysis of visual information processing in terms of stores, but it need not complicate the distinction between sensory, schematic, and verbal forms of representation. An attempt to clarify this suggestion is illustrated in Fig. 7. The
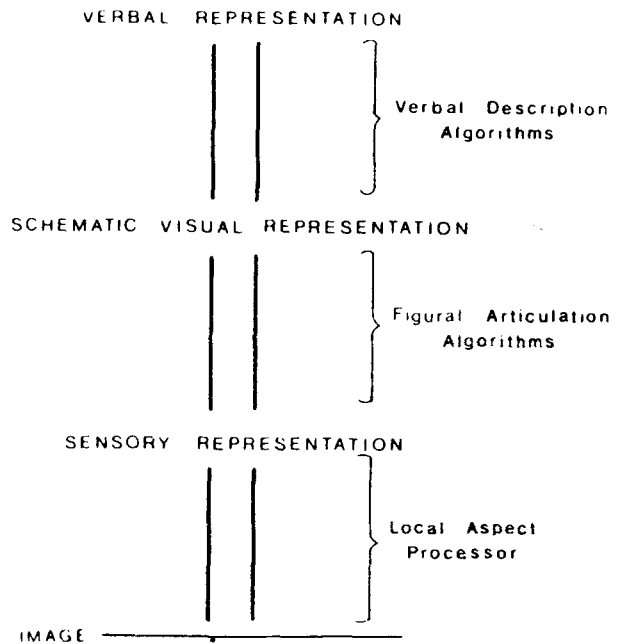

Fig. 7. Hypothetical classes of representation and the relations between them. The image is the optical pattern formed upon the retinae. The figure is not a flow diagram but suggests that higher representations are built upon lower representations. Although representations are assumed to have independent significance, the possibility is left open that they also serve as addressing mechanisms for lower representations.

sensory representation is the set of properties computed by the sensory system, and is approximately equivalent to the crude features of the stimulus signaled by the peripheral nerve nets in Turvey's (1973) model. Its most important characteristic is, perhaps, that all sensory properties are functions of a small, and usually spatially local, fragment of the total stimulus input. They can therefore be computed by neural mechanisms that are tied to fixed local regions but which are replicated many times across the sensory surface and which operate concurrently and independently. On this hypothesis, models of sensory storage can be seen as mainly concerned with the temporal aspects of the computation and preservation of sensory properties. If these differ for different properties, then measures of storage time, etc., will vary in a confusing way to the extent that different methods depend upon the use of different sensory properties. As these properties are all computed in essentially the same way, however, they are likely to share some basic storage characteristics. That is, all forms of sensory storage are likely to be high-capacity and topological because they involve mechanisms replicated many times across the sensory surface; they are likely to be brief because their high capacity makes internal maintenance difficult; and they are likely to be sensitive to masking because the properties represented are closely tied to the sensory surface.

It is suggested that the schematic visual representation is a figural articulation of the sensory representation that shows how selected elements can be related to each other to form figures or parts of figures. Such an articulation is likely to be closely related to an interpretation of the input in terms of objects, etc., and is similar to the schematic map suggested by Hochberg (1968). The main characteristic proposed for figural properties is that they cannot be defined in terms of any explicit combination of local properties. In other words, they are not tied to the sensory surface, and are closely analogous to properties, such as connectivity, which were shown by the formal analysis of Minsky and Papert (1969) not to be computable by any diameter-limited or order-restricted perceptron. The computation of figural properties therefore seems to be more difficult than the computation of sensory properties and cannot be achieved by mechanisms tied to the sensory surface. This, in turn, suggests that schematic visual representations will be of limited capacity but neither topological nor sensitive to masking.

The hypothesis suggested above is similar to that of Coltheart (1972) but differs in at least one important respect. Coltheart proposes that the verbal representation is computed directly upon the sensory representation. One reason for supposing that the schematic representation mediates between sensory and verbal representations is the lack of any interaction between the letter position effect and the

effective duration of stimulus availability in word recognition experiments (Phillips, 1971). A more general reason is that verbal descriptions based upon abstract visual structure seem both more tractable and more useful than those based upon sensory detail.

It seems clear that the performance ascribed to STVM is not due to sensory storage, but there remains the problem of showing clearly why it is not due to verbal memory. Although the experiments were not primarily concerned with this issue, three aspects of the results seem relevant. Firstly, the level of performance to be accounted for is over 80% discrimination between two novel 5 by 5 block patterns differing by only one element. The representation supporting this performance must be produced in 1 sec or less, and must be maintained for some seconds. It seems highly unlikely that there is any verbal description sufficiently succinct to meet these requirements, and one is not available to Ss when they are asked to describe such patterns, for they then have to work hard for many minutes to produce a description. Secondly, any verbal description that is involved must be produced and used without the S's being aware of it. Ss report that they are only rarely aware of verbalization in Experiment I, and that they are not aware of any verbalization in Experiments II and III. Paivio and Bleasdale (1973), studying memory for the same kind of patterns, obtained similar reports. Finally, Experiment I showed forgetting over unfilled intervals of a few seconds. This does not usually occur when verbal materials are to be retained over such intervals (e.g., Williams et al, 1969).

The STVM suggested by the above results is similar to Posner's visual code for letters with respect to its limited capacity, and its protection from masking. It appears to differ, however, with respect to its durability. There is evidence that if S is given sufficient incentive to concentrate on the visual code, it decays little, if at all, over periods at least as long as 25 sec (Kroll et al, 1970). There seems to be little doubt that in the present experiments Ss were concentrating on the visual appearance of the patterns, yet there was still rapid loss over the first few seconds. A possible reason for this is that if familiar forms, such as letters, are to be compared, then the well-established knowledge of their appearance can be used to create or maintain the representations involved in the comparison. The results indicate that it would be misleading to describe STVM as involving a relatively pure visual or physical trace, particularly as these terms seem more applicable to the sensory representation. It is important to note that STVM involves a schematic representation of strictly limited capacity, rather than a fading image of some kind. It is possible that Pollack (1972) failed to find evidence of STVM because, in his experiments, Ss had to detect changes in the position of isolated dots, and such changes may have had little effect on any

schematic representation formed. Furthermore, his patterns were displayed for only about 12 msec, and this provides little time for the construction of any such representation.

Use of the phrase "short-term visual memory" may be taken to imply that the STM-LTM distinction well known in verbal memory also applies to memory for schematic visual representations. There is no wish to preempt this issue, however, and the visual memory observed is called short-term only because it deteriorates greatly within 10-20 sec.

Finally, it may be worthwhile to speculate on the function of STVM. Neisser (1967, p. 141) discusses the distinction between sensory and schematic representations in relation to the problems of temporal integration in visual perception. He presents the argument that perception must involve some kind of memory because of the necessity to relate the inputs from successive fixations, and asks whether the icon is the mechanism whereby such an integration is achieved, or whether the icon acts as an obstacle to such an integration because of being retinally fixed. The above results indicate that the sensory representation is retinally fixed and therefore cannot integrate input from successive fixations. Sensory storage need not be an obstacle to such an integration, however, because it does not interfere with STVM, and STVM does not seem to deteriorate over the first 600 msec. It is possible, therefore, that one function of STVM is to relate successive inputs so as to produce a representation of the visual environment that extends beyond the momentary input.

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